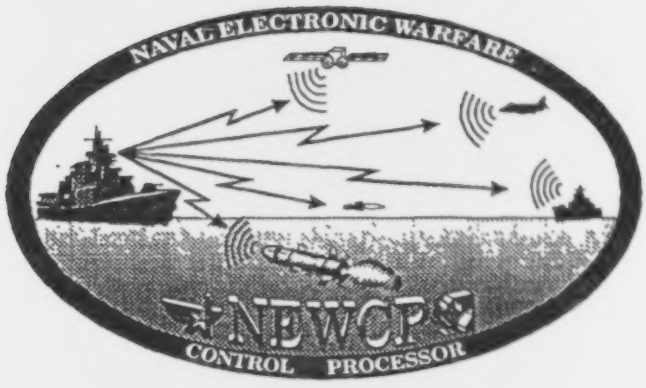

The Integration Of
Electronic Warfare Assets On
Maritime Platforms
PHASE I

SYSTEM DESIGN, EVALUATION, & TEST

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THE INTEGRATION OF ELECTRONIC WARFARE ASSETS ON MARITIME PLATFORMS PHASE 1

SYSTEM DESIGN, EVALUATION, & TEST

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LIST OF ABBREVIATIONS

AAW	Anti air warfare
AOD	Active offboard decoy
ARM	Anti-radiation missile
ASM	Anti-ship missile
B/L	Breaklock
BB	Blackboard
BM	Battle manager
CCS	Command and control system
CPF	Canadian patrol frigate
CPF	Canadian patrol frigate
DM	Device manager
EA	Effectiveness assessment
ECCM	Electronic counter countermeasures
ECM	Electronic countermeasure
EM	Engagement manager

EMCON	Emission control
EPM	Electronic protective measures
ESM	Electronic support measures
EW	Electronic warfare
FOV	Field of view
FRS	Functional review specification
HADF	High accuracy direction finding
HK	Hardkill
HOJ	Home on jam
IR	Infrared
IRCS	Infrared cross section
IRST	Infrared search and track
KB	Knowledge base
LET	Leading edge tracking
LOS	Line of sight
NCP	Noise cover pulse
NEWCP	Naval electronic warfare control processor
OMI	Operator machine interface
PLE	Predicted level of effectiveness
PRF	Pulse repetition frequency
PRI	Pulse repetition interval
PW	Pulse width
RB	Rubber duck
RCS	Radar cross section
RF	Radio frequency
RGPO	Range gate pull off
RPV	Remotely piloted vehicle
SDF	Sensor data fusion
SK	Softkill
SSRM	Swept scan rate modulation
SWT	Search while track

TM	Tactical manager
TSA	Tactical situation assessment
UMS	Uncertainty management system

1.0 Introduction

This report presents a preliminary functional design of the EWCP processor and a proposed work plan and cost for Phase 2 of "The Integration of Electronic Warfare Assets on Maritime Platforms".

The preliminary functional design elaborates on the i) main components of the NEWCP, ii) functionality of components and component inter-relationships, iii) dataflow between components, and iv) distribution of functionality between the CCS and the EWCP. The design provides sufficient detail to support the definition and specification of the implementation work to be carried out in Phase 2. The second phase will include algorithm development, the execution of experiments and the collection of associated data, and the use of simulation to verify concepts.

The detailed work plan will specify work elements, associated cost, schedule information, and associated risk where applicable. Milestones and meetings with the customer will be specified as well as the various deliverables associated with the different tasks of Phase 2.

2.0 CCS / NEWCP Distribution of Functionality

2.1 Introduction

The purpose of this section of the report is to describe the distribution of functionality between the CCS and the NEWCP. A wide range of evaluation and decision-making functions need to be made in support of EW activities. Accordingly, there is a requirement to partition these functions between the CCS and the NEWCP.

A variety of options have already been identified for the partitioning of functionality between the CCS and the NEWCP. These are described in detail in section 4 of the task 2300 report. The decision of which, if any, of these options to implement depends on a number of factors including project funding and schedule (which have not yet been established). Accordingly it would be premature to commit to a particular option.

Notwithstanding this uncertainty, the distribution of functionality between the CCS and the NEWCP will be discussed in terms of options 3 and 4. It is to be noted that these options differ only in the fact that under option 3, the CCS is responsible for sending engagement orders to the ECM assets whereas this responsibility is borne by the NEWCP under option 4. Option 3 / 4 is considered to represent the most natural distribution of functionality, where all functions requiring detailed EW knowledge are embedded within the NEWCP.

Following an overview of the functional distribution associated with this option, a preliminary specification of the data flow between the CCS and the NEWCP will be provided.

2.2 Distribution of Functionality (CCS - NEWCP)

Under the proposed functional distribution, the NEWCP is responsible for determining the specific countermeasure (or set of countermeasures) to be implemented, performing assessments of the effectiveness of deployed countermeasures, and for performing tactical situation assessments. The division of functionality in each of these three areas will now be addressed in more detail.

As is the case for all four of the proposed options for distribution of functionality, the NEWCP supplements the tactical situation assessments performed by the CCS. The design principle is that of complementarity - the NEWCP will add assessments, based on its specialized knowledge of the EW problem domain, to the CCS tactical picture. The distribution of TSA responsibility between the CCS and the NEWCP is addressed in detail in section 3.3. However, a brief summary of this material is provided as follows.

The CCS provides tactical situation (TSA) data concerning the positions of both friendly and hostile emitters and platforms along with an estimation of the enemy order of battle. In addition,

the CCS TSA function keeps track of ownship / Force platform position and velocities, performance limits associated with ownship sensors and hardkill weapons, status and operating parameters of ownship / Force sensors and hardkill weapons, stock level of hardkill munitions, etc. If the CCS is responsible for designation to ECM assets (i.e. option 4), it will need to include ECM asset status in the tactical assessments that it formulates.

The responsibilities of the NEWCP with respect to TSA include all those assessments that require a detailed and specialized knowledge of EW. Such assessments are provided in section 3.3 of this report and are not provided here for the sake of brevity. In general terms, however, these assessments can be classified into three categories: threat assessments, defence assessments, and environmental assessments. The NEWCP is responsible for all tactical assessments that require EW knowledge and / or support the prosecution of targets specifically using ECM assets.

Under the proposed functional distribution, the NEWCP is responsible for determining the ECM techniques to use against the threat. The NEWCP makes its ECM selection based on predicted effectiveness as well as high level deployment issues such as fratricide, interference, and own ship's/fleet's tactical objectives. Although the NEWCP provides high level assessments about such issues, the final responsibility for resolving these ship and Force level issues is retained by the CCS. In support of this, the NEWCP provides the CCS with parameters such as the predicted effectiveness and time to implement associated with the recommended countermeasure deployment.

Virtually all command decision functionality with respect to the deployment and control of EW assets resides within the NEWCP; however the CCS will always have the power to veto engagement decisions produced by the NEWCP. The NEWCP also has significant functionality in support of hardkill/softkill coordination. Under one variant of the proposed functional distribution (option 3), the CCS is primarily responsible for sending the appropriate designation commands to the various ECM assets upon receiving recommendations from the NEWCP. Under the other variant (option 4), the NEWCP transmits designations directly to the ECM assets.

The NEWCP is responsible for the execution of effectiveness assessment activities related to the use of EW assets. More specifically the NEWCP will perform assessments concerning radar mode changes, trajectory deviations, and chaff reflections. Although effectiveness assessment based on jog detection is an important component of the effectiveness assessment function, the extremely short reaction time required strongly favours the implementation of this capability within the ECM asset themselves (e.g. RAMSES). Finally, the NEWCP also contributes to a determination that the threat is no longer physically capable of intercepting ownship (e.g. based on a knowledge of threat seeker field of view, the threat cannot possibly reacquire the ship).

Under the selected distribution of functionality, the CCS also informs the NEWCP of ship's doctrine, intentions, and priorities to help the NEWCP formulate an effective ECM tactic based upon these high level issues. Of particular significance in this regard, the CCS is responsible for

threat prioritization and will designate threats to the NEWCP based upon such threat assessments. The CCS will also provide any meteorological that it may have to the NEWCP.

Another important aspect of the relationship between the CCS and the NEWCP relates to the issue of sensor cueing. The NEWCP should have the capability of requesting the services of a CPF sensor. Principle reasons for such requests include attempts to reduce ambiguity in NEWCP tactical situation assessments and EW effectiveness assessment activities. It is envisioned that the NEWCP will have to request such sensor services from the CCS which, based on its knowledge of the relevant priorities of all combat system activities, will either accept or deny the request.

2.3 Data Flow (CCS → NEWCP)

In accordance with the distribution of functionality described in section 2.2, the following data will be provided to the NEWCP by the CCS:

- EW Operations Constraints:
  - Spatial;
  - Spectral;
  - Temporal;
  - Asset utilization.
- Threat Designation:
  - Threat priority;
  - Zone in which threat is to be engaged.
- Request for NEWCP Predicted ECM Effectiveness
- CCS Tactical Situation Assessment:
  - Track position, velocity, acceleration, and heading;
  - Order of battle.
- Sensor Status:
  - Available;
  - Degraded;
  - Unavailable.

- Meteorological Data:
  - Wind direction;
  - Wind speed;
  - Precipitation;
  - Sea State.
- Supplementary Threat Data:
  - Attributes (e.g. PRF);
  - Identity;
  - Mode of operation.
- Fleet NEWCP Coordination
  - Cooperative jamming techniques.

2.4 Data Flow (NEWCP → CCS)

In accordance with the distribution of functionality described in section 2.2, the following information will be provided to the CCS by the NEWCP:

- Threat Engageability:
  - Probability of target softkill;
  - Time to accomplish target softkill.
- EW Resource Status:
  - Asset available;
  - Asset degraded;
  - Asset unavailable.
- EW Tactical Situation Assessments:
  - Disposition of ECM assets (e.g. position, operating state);
  - Predicted threat actions (e.g. imminent missile launch).
- EW Effectiveness Assessment:
  - Certainty factors.

- Manoeuvre Requests:
  - Heading;
  - Velocity.
- Sensor Cueing Requests

3.0 Main NEWCP Components

This section elaborates upon the main functional components of the NEWCP design and the inter-relations of each component in terms of data flow and hierarchy. The principal functions include: i) EW deployment, ii) effectiveness assessment (EA), iii) EW tactical situation awareness (TSA), iv) blackboard, and v) knowledge base. Refer to figure 1 for a conceptual illustration of the NEWCP, including its key functional components, along with the CCS and sensors. The preliminary design is based upon the results obtained from the previous three sub-tasks of the NEWCP project, including: i) requirements analysis and AAW review, where a preliminary functional requirements specification (FRS) was produced, ii) effectiveness of countermeasures, where effectiveness assessment and related items were addressed, and iii) softkill deployment and control, where the issues of developing softkill and placing control of ECM deployment were investigated.

Four deployment options were presented in the "softkill deployment and control" task of the NEWCP project, ranging from the NEWCP providing ECM engageability advice to the CCS to the NEWCP controlling the individual ECM assets to coordinate countermeasures. The functional modules shown in the figure are relevant to the third and fourth design options of deployment control.

3.1 EW Deployment

The EW deployment module is responsible for formulating ECM techniques and tactics to counter both RF and IR threat systems. Deployment is based upon a layered defence approach, whereby countermeasures is selected on the basis of the phase of the threat. The four layers are avoidance, confusion, dilution and seduction, of which the last three are applicable to the NEWCP. The table below lists the relevant defence layers and corresponding threat phases.

Defence Layer	Threat Phase
Confusion	Search/Targeting Radar
Dilution	Seeker Search/Acquisition
Seduction	Seeker Lock-on

The design approach for EW deployment is based on a hierarchichal reasoning structure, comprising four principal levels: the EW battle manager (BM), EW engagement manager (EM), EW tactical manager (TM), and device manager (DM). Each level or manager is responsible for unique tasks, working collectively to defeat the threat(s) with softkill. Dividing the EWCP into four levels facilitates parallel processing, whereby several managers can perform their tasks simultaneously to enable the NEWCP to engage multiple threats in real-time. Real time

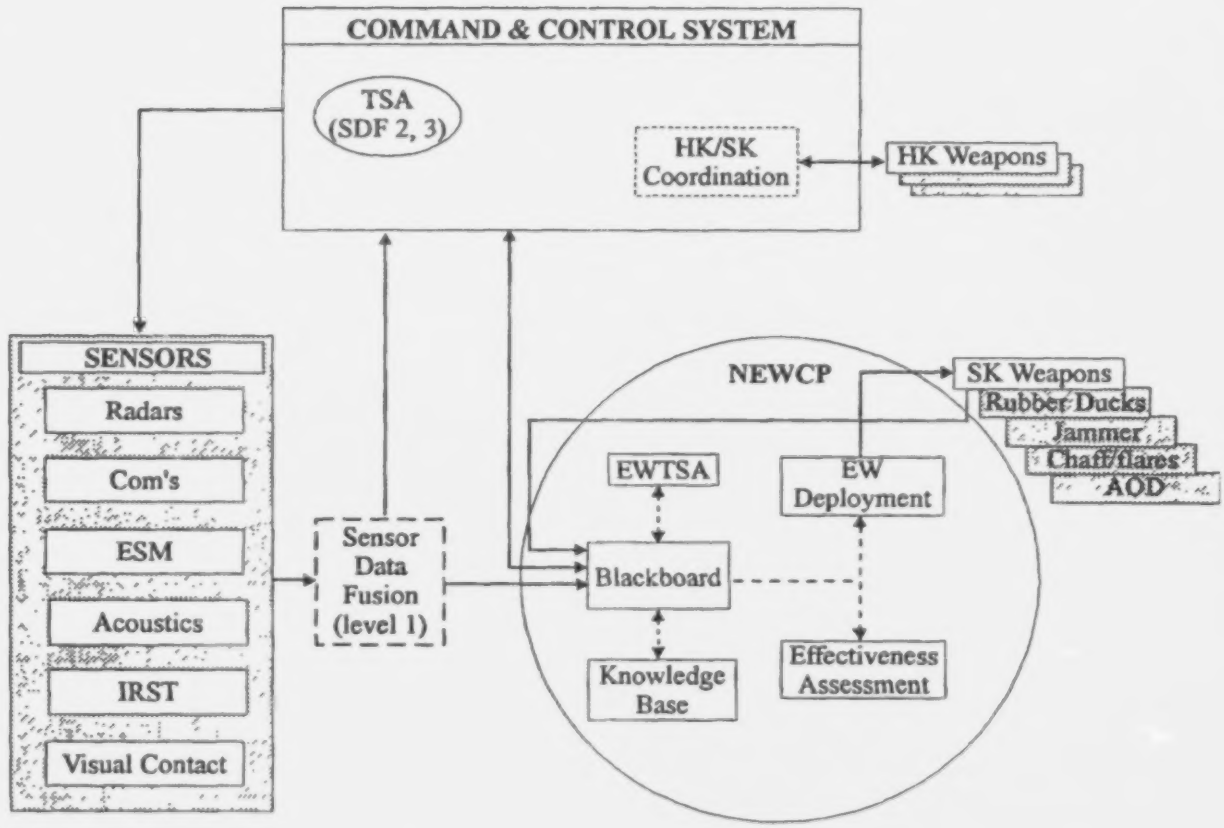
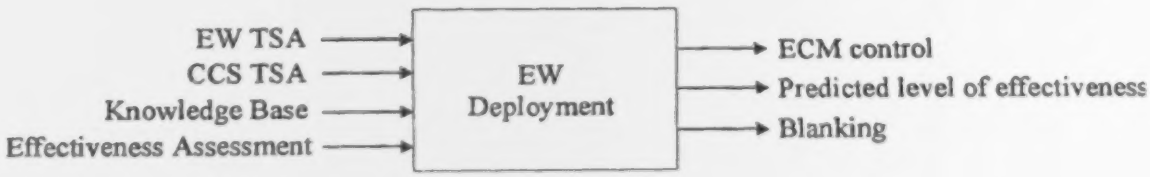


Figure 1. Conceptual block diagram of NEWCP.

processing represents a critical feature of the NEWCP, and will have a significant impact on the design of both the hardware and software architecture of the NEWCP.

Figure 2 provides a conceptual illustration of the varying levels of functionalities within the EW deployment module. As shown, the primary external functions interfacing to the deployment module are the CCS and SDF, and the ECM assets via the EW bus. The input data, feeding the deployment algorithms, are the EW TSA, CCS TSA, knowledge base, and the effectiveness assessment. The output of the deployment module includes: i) ECM commands, to control the various EW assets, ii) predicted level of effectiveness for each recommended countermeasure technique, and iii) blanking commands to eliminate or minimize interference with shipborne sensors (see figure below).



As shown in figure 2, the BM resides at the top of the hierarchy structure, accepting commands from the CCS and coordinating the activities of the EW engagement managers as they respond to individual threat systems. Based upon CCS instructions, the BM considers high level deployment issues such fratricide, electromagnetic interference, hardkill/softkill coordination, stock levels of ECM assets, etc., and controls the individual EM's accordingly.

The EM is responsible for engaging a single threat, as commanded by the BM, until the threat is either defeated or the BM sends a halt command. The EM's first task is to determine the EW layer in which the threat resides, and select the appropriate EW tactical manager to execute ECM techniques. The EM will be presented with multiple choices of countermeasure tactics provided by individual EW tactical managers (TM). The EM bases its selection of ECM tactics in accordance with the constraints established by the BM, as well as other considerations.

The EW tactical manager is responsible for formulating a series of tightly coupled ECM techniques to engage the threat, along with a predicted level of effectiveness (PLE) to help the EM in its selection process. The TM closely monitors the progress of ECM, through the EA module, and makes changes to deployment where necessary. The device manager receives deployment instructions from the TM, and interprets them into designation commands which are sent to the individual ECM assets via the EW bus. The following sections elaborate upon each of the deployment managers.

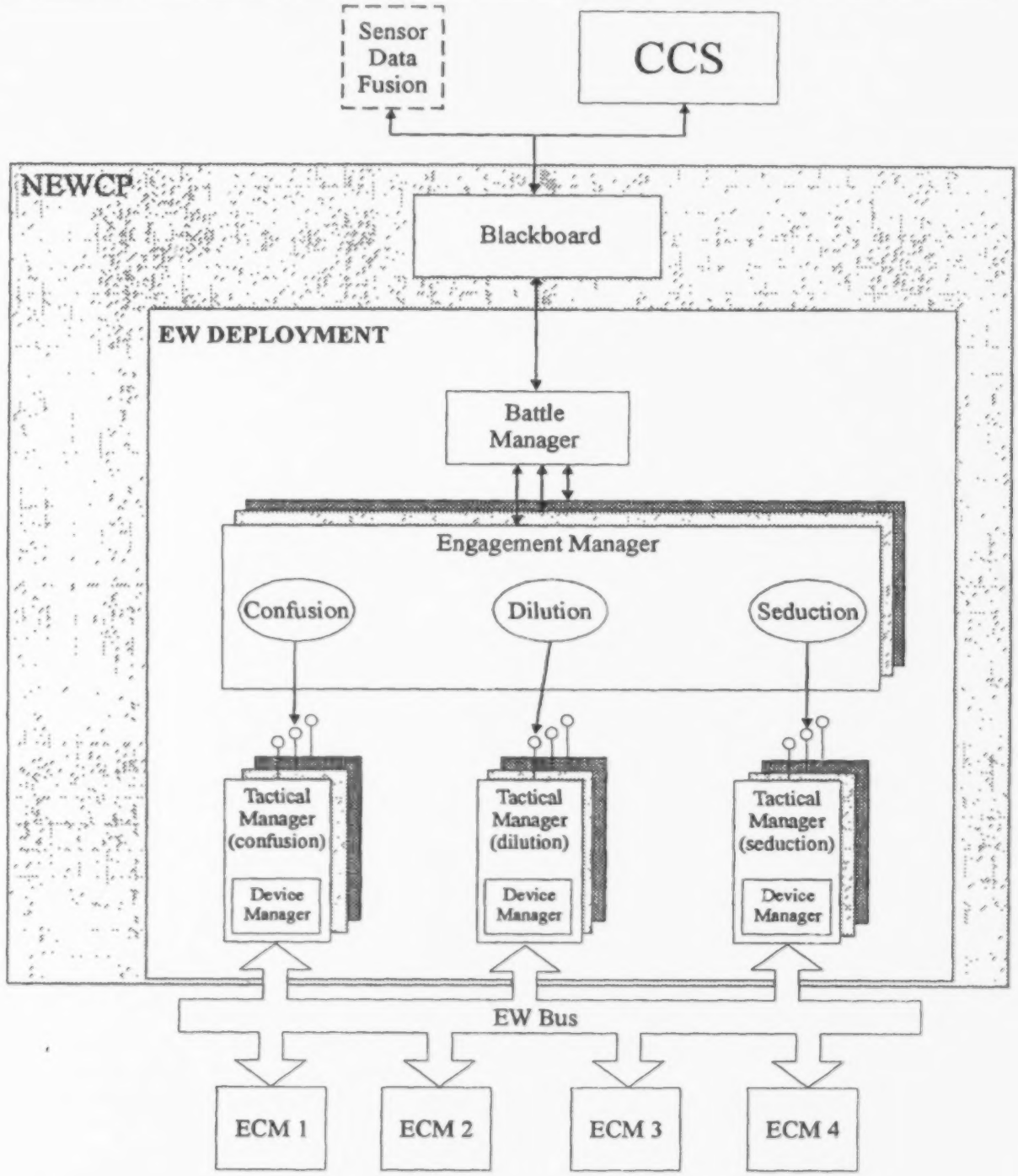


Figure 2. Block diagram of the EW deployment module.

3.1.1 EW battle Manager

The primary role of the BM is to assess the combat scenario, from an EW perspective, and coordinate simultaneous engagements. The BM deals with each threat on a priority basis, as defined by the CCS. All ECM assets and activities are closely monitored by the BM, and any resource conflicts or limitations that are occur are resolved in favour of the higher priority threat. The BM, at the request of the CCS, considers the consequences of ECM deployment in terms of fratricide and interference, and chooses ECM tactics which eliminate or minimize these problems while still achieving the required countermeasures effectiveness. In addressing fratricide and interference, the BM requires various types of information, some of which are listed in the table below:

Data	Fratricide	Interference
Own ship position, heading, and speed	✓	
Own fleet ship positions, headings, and speeds	✓	
Missile position, heading, and speed	✓	
Environmental effects on ECM deployment (e.g. wind)	✓	✓
Movement of ECM decoy (e.g. drone, RPV, etc.)	✓	✓
Own ship sensors - LOS/FOV - operating parameters -		✓
Own fleet ships sensors - LOS/FOV - operating parameters		✓

The BM is responsible for maintaining the EW TSA, which is overlayed with the TSA data provided by the CCS, as discussed in section 3.3 of this report. The CCS TSA is responsible for all non-EW elements of the EW battle, including the state-vectors and identifications of all platforms and associated emitters, the lethality of all threats, etc., while the BM keeps track of EW related factors, such as current and previous ECM deployment and state, enemy ECM and ECCM, etc.

The BM provides the necessary data to support the EWCP display. Figure 3 illustrates how a typical display may appear. The top figure represents the standard or main screen with the EWTSA in the upper left hand corner. The right hand side of the display shows track reports for the two highest priority threats, including a list of countermeasures being executed (shaded portion) and those planned for the engagement. The lower left portion of the screen includes the

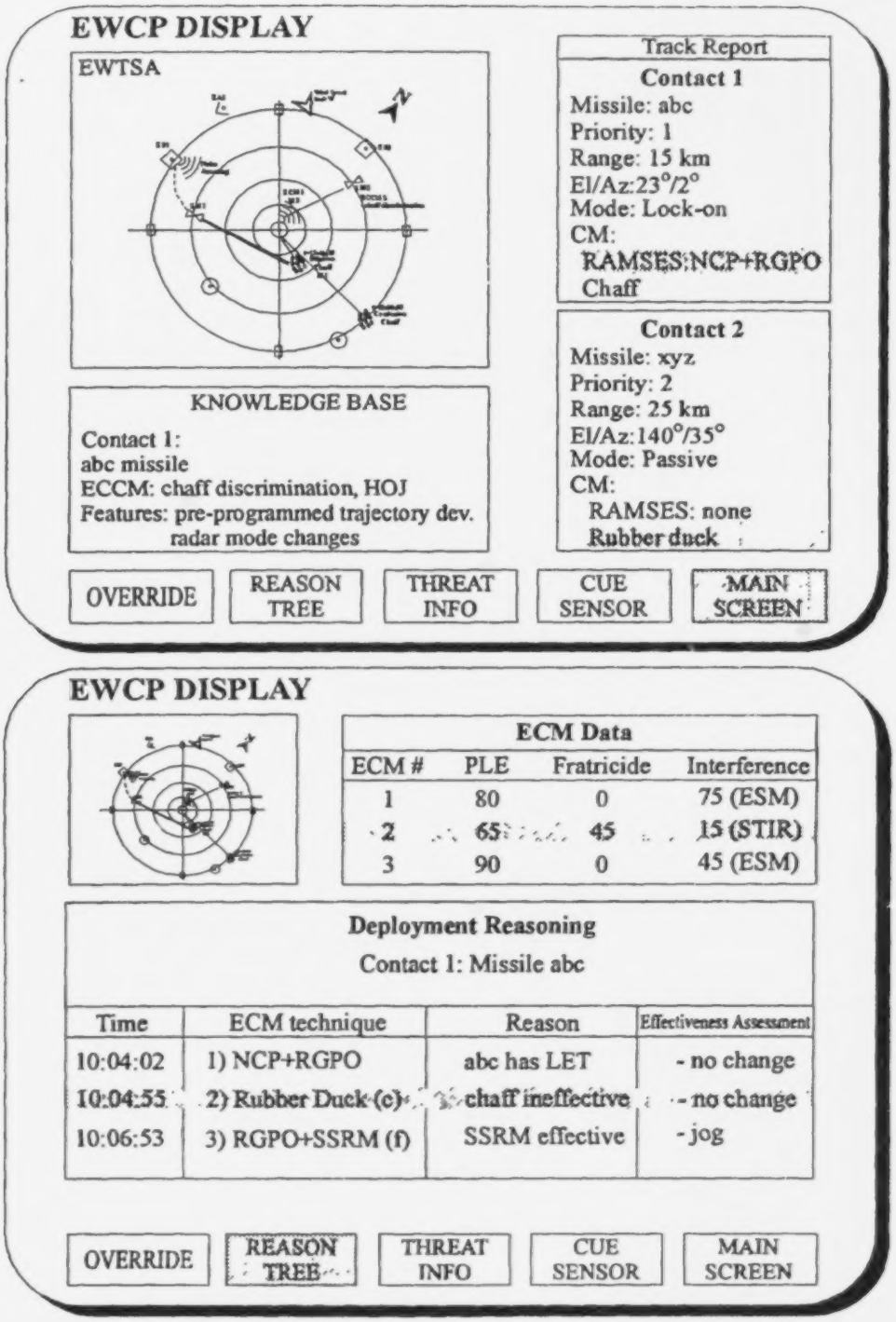


Figure 3. An example of a NEWCP display.

knowledge base window which provides information regarding missile 'abc'. The set of menu buttons at the bottom of the screen represents the input interface to the EW operator, and includes input commands to: override NEWCP, invoke the reason tree, display more detailed threat information, and cue sensors. The override command disengages the NEWCP, so that the CCS or EW operator has control over the ECM assets directly, which is the case for the current CPF configuration. The threat information button provides the EW operator with detailed information regarding a particular threat, in addition to what is already displayed on the screen. This information may include measured radar parameters such as PRI, frequency, pulse width, etc., and/or an elaboration of knowledge base data including lessons learned from previous engagements against a particular threat system, etc. The cue sensor button allows the operator to request sensor cuing, via the CCS, to support countermeasures deployment.

The reason tree button allows the operator to review all deployment decisions made by the NEWCP for a particular threat. The bottom display in the figure gives an example of what the deployment reasoning tree may look like. In this example, there are four elements to the tree: time, ECM techniques deployed, reason for deployment, and effectiveness assessment results. At each time interval, the tree shows precisely which ECM technique was deployed and the reason behind it, and the corresponding measured EA. For example, the display shows NCP was executed because the threat has leading edge tracking (LET). To achieve an angle displacement, a rubber duck (RB) decoy was deployed at 10:04:55 - the RB was used because chaff is known to be ineffective. At 10:06:35, the EA reports that the RB is ineffective, since no trajectory change was measured, hence, the NEWCP executed RGPO followed by coarse SSRM (C). The coarse SSRM technique employs relatively wide frequency limits and high sweeping rates. Upon registering a jog, the NEWCP executes fine SSRM (narrow frequency limits and slower sweep rate), which results in a breaklock (B/L) as reported by the EA module.

The upper right hand box, titled 'ECM data', provides additional information regarding the deployment of each ECM technique shown in the 'deployment reasoning tree' box. For example, it indicates for ECM technique No. 1 (NCP + RGPO) that the predicted level of effectiveness (PLE) is 80 %, while the potential for it to introduce fratricide is 0 %, and interference is 75 % (with the ESM system).

The figure presents just one example of a NEWCP display. Research into operator machine interfaces (OMI), as well as other aspects of human engineering, will be required for the final display design. It is envisaged the display will be completely configurable, based on a windows type environment, where multiple windows can be opened and moved around to meet the operator's customization requirements. Operator input may be facilitated through softkeys on the screen, as shown in the figure, or through a mouse or keyboard.

The following list summarizes the types of information that may be presented on the NEWCP display:

- EWTSA
- Current ECM deployment and predicted level of effectiveness (PLE)
- Deployment reasoning tree
- ECM resource status/stock level
- Knowledge base on specified threats
- Environmental effects
- Detailed data on measured threat attributes

The BM receives all external data and commands through the blackboard, and sends data and cuing requests via the same interface. Refer to the section 3.5 for a high level description of the blackboard. The type of effectiveness assessment performed at this level includes missile kill.

The EW battle manager functionalities, described above, will be implemented primarily in software algorithms, based on cooperating expert systems.

3.1.2 EW engagement manager

The EM is responsible for engaging a single threat with ECM, as instructed by the BM, until the threat is either defeated or the BM sends a halt command. The first task the EM performs, upon receiving a designation command, is to determine the defence layer in which the threat resides. The EM uses threat information such as platform type, relative range, identification, and radar mode to establish if the threat is in the confusion, dilution, or seduction stage of engagement.

Once the EM determines the relevant defence layer, it selects the corresponding EW tactical manager (TM) to derive a softkill solution. For each layer, there are multiple TM's working in parallel to offer the EM different ECM options against the same threat. Each TM would consider a pre-defined countermeasure tactic that is fined tuned for the threat of interest. For example, one ECM tactic may include the execution of NCP + RGPO + SSRM, while another ECM tactic may include RGPO + chaff. The parameters for each technique (e.g. bandwidth of NCP = 22 MHz, RGPO acceleration = 6 m/s^2, etc.) are dynamically set to maximize ECM effectiveness against the specific threat. Associated with each ECM option is a predicted level of effectiveness which helps the EM in its selection process. Of course, the final decision concerning deployment does not rely solely on maximum ECM effectiveness, but also on other high level deployment factors such as fratricide, interference, HK/SK coordination, etc., as discussed previously.

The principal reason for utilizing multiple TMs, operating simultaneously against a single threat, is to allow the NEWCP to derive an optimal solution in real-time, which is critical particularly in a dense threat environment. In addition to ECM techniques being derived in the current layer, the TMs of the remaining layers work on solutions that are to be implemented later on, when the threat falls within the specific layer. This allows the NEWCP to operate in an anticipatory manner, rather than simply responding to events as they occur.

The EM also refers to the knowledge base (KB) module to review the outcome of past engagements with the present threat to determine which ECM techniques/tactics to pursue or avoid. Effectiveness assessment at this level includes the measurement of trajectory deviations and chaff cloud reflections, as discussed in section 3.2 of this report. If the current ECM technique is effective, as determined by the EA module, then the EM would continue utilizing the TM, which is responsible for the ECM, until the threat is defeated. If, on the other hand, ECM is ineffective, then the EM would select another TM solution, and advise the BM accordingly.

The EM indicates to the BM the current ECM tactic being executed and the likelihood of success. The EM accepts all constraints imposed by the BM, and passes them along to the TMs so that unnecessary processing is avoided. For example, the BM may command that there be no chaff deployment, hence, all TMs utilizing chaff would be disabled.

3.1.3 EW tactical manager

The EW tactical manager executes a tightly coupled series of ECM techniques on command by the EM. Each TM is responsible for coordinating unique techniques and tactical combinations, and indicating the predicted level of effectiveness (PLE) for each one. The TM also reports the expected response of the threat for a given countermeasure (e.g. seeker should break lock and enter into reacquisition mode when exposed to X-pol). An example of an EW tactical manager configuration is shown in figure 4 for the seduction layer. Three different EW tactical managers are depicted with their associated ECM tactics, including: i) RGPO + chaff, ii) NCP + RGPO + SSRM, and iii) X-pol. The PLE is 75 % for the first tactic, 64 % for the second, and 80 % for the final one. A pre-defined lower PLE limit would be specified to avoid unnecessary processing. For example, the EM may establish a PLE minimum of 50 %, so that any ECM with a lower PLE value would not be considered. Note the PLE for each manager changes dynamically as the engagement unfolds, as circumstances arise which either increase, decrease, or pose no impact on the effectiveness of a particular tactic. As shown in the figure, each box contains a criteria which defines when the subsequent box can be executed. For example, for the X-pol TM, it is seen that coarse X-pol is applied immediately, followed by fine X-pol only when a jog is detected.

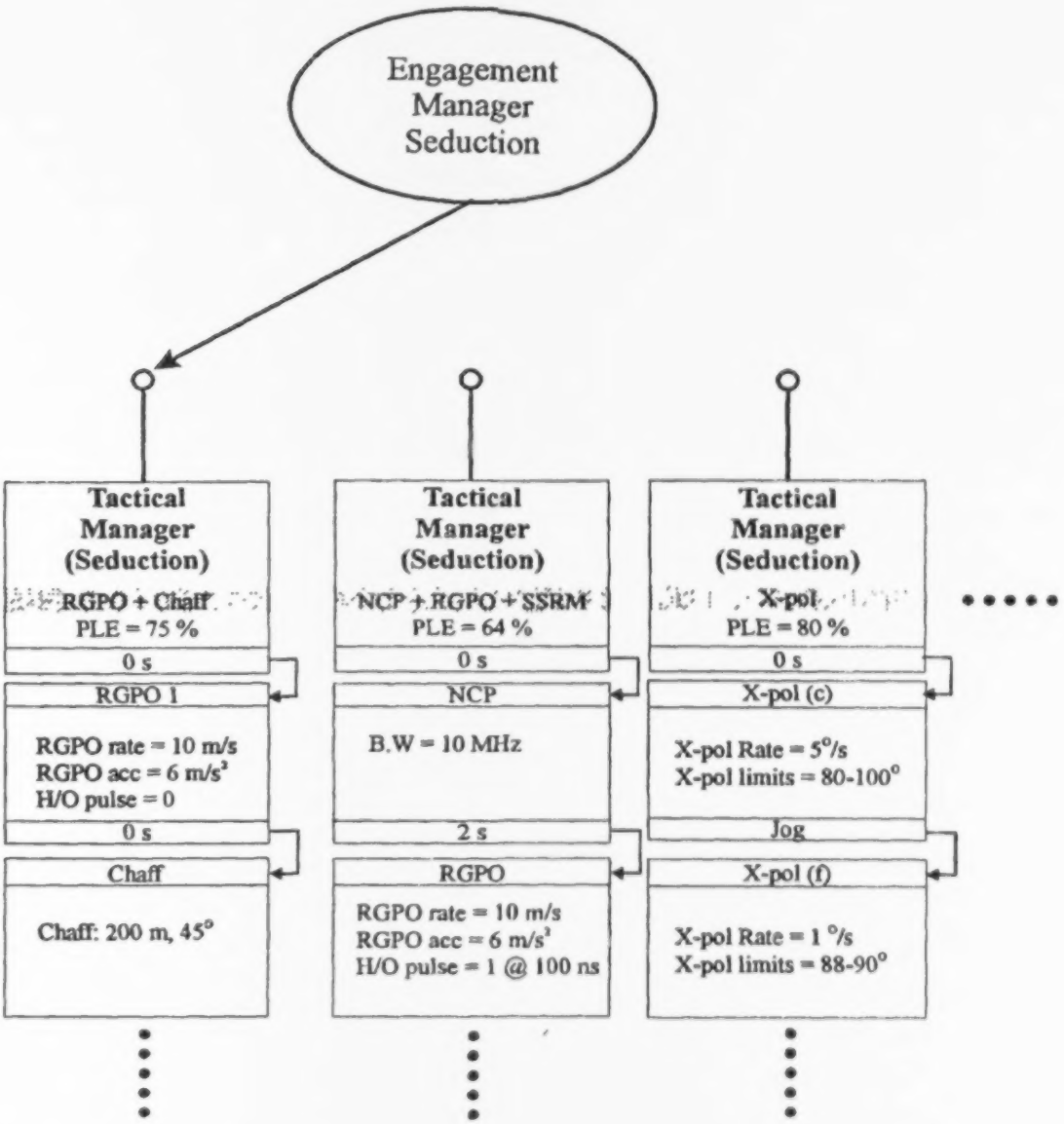


Figure 4. Example of seduction EW tactical manager.

For each TM, the parameters associated with the pre-defined countermeasures are dynamically set according to the threat and scenario. For example, it is shown for the RGPO + chaff TM, the rate and acceleration regarding RGPO has been dynamically set to 10 m/s and 6 m/s^2, respectively, to correspond to the operating characteristics of the seeker's range tracker. Also, the chaff deployment is specified for a 200 m range and 45° azimuth angle launch, based on ship heading, missile range and approach angle, and wind speed and direction. To derive the necessary parameters for each ECM technique, the TM algorithms require significant information regarding: own ship/asset data, threat characteristics, environmental conditions, ECM capabilities/stock level, and effectiveness assessment results.

Own ship/asset data

- EW weapons status
  - stock level, limitations, operational status
- Ship Manoeuvres
  - heading, speed, acceleration
- Ship doctrine
  - combat role (e.g. point or area defence), planned tactics
- ECM deployment state
  - decoy position, decoy state of effectiveness (e.g. chaff RCS size)

Environmental Conditions

- Sea State
  - clutter, multipath, depolarization
- Atmospheric attenuation
- Refraction
  - trapping (ducting), super-refractive, normal, sub-refractive
- Wind
  - speed, direction

Threat information

- Attributes
  - frequency, PRI, PW, PRI stagger, RF jitter capability, etc.
- Platform type
  - land, sea, air, sub-surface
- Identification
  - platform name, radar/IR name
- State vector
  - position, velocity, heading, acceleration
- Operation mode
  - search(fine, coarse), SWT, (re)acquisition, track, HOJ
- Features
  - ECCM, War Modes, pre-planned trajectory manoeuvres, etc.

ECM Capabilities

- Chaff
  - deployment range and angle, bloom time, maximum RCS, etc.
- Flares
  - deployment range, angle, maximum IRCS, etc.
- Rubber ducks
  - expansion time, maximum RCS
- Jammer
  - search and lock-on techniques, (range deception, angle deception)

Effectiveness Assessment Results

- jog, kill, radar mode changes, trajectory deviations, chaff cloud reflections

The effectiveness assessment events that are applicable to the EW tactical manager include jogs, radar mode changes, and chaff reflections. The EW tactical manager uses the EA information to i) continue the current jamming sequence, if the threat is being adversely affected, ii) fine-tune ECM technique parameters, if the threat is experiencing slight disturbances, or iii) halt ECM, if the threat is being unaffected. For example, if coarse SSRM causes a jog, then the TM would resort to fine SSRM to continue countering the threat.

The TM also has to contend with uncertainties from within and external to the NEWCP when deriving ECM tactics. The following list describes where uncertainties may arise:

- Environment
  - multipath, clutter, precipitation, refraction, etc.
- Sensors
  - resolution, accuracy, receiver noise, sensitivity, etc.
- Sensor data fusion
  - alignment, correlation, tracking, identification, attributes, etc.
- EWTSA
  - EW placements, ECM conditions, alignment with CCS TSA

- Knowledge base
  - inaccurate intelligence, incomplete intelligence, War Modes

- Effectiveness Assessment
  - latency effects in comparing measured to expected

The algorithms used to implement the functions within each EW tactical manager would be written in an expert system environment.

3.1.4 Device Manager

The device manager (DM) essentially interprets deployment commands from the EW tactical manager into designation commands for each ECM device. The DM interfaces with each equipment via the EW data bus, which may be similar to the current SHINPADS architecture, or perhaps something more advanced such as an ethernet link. A DM exists for each TM, hence, a single DM may handle many ECM devices, depending on the number of unique techniques programmed. A bus scheduler on the EW data bus handles the traffic flow of data originating from each DM to the individual devices (note the DM does not necessarily represent individual hardware systems, and may in fact be software routines/objects). A priority matrix is established, by the BM, which is propagated down to the DM to resolve resource conflicts. If more than one DM requires the same ECM asset, than the higher priority threat is allocated the resource until it is no longer required.

The DM also monitors the state of the EW asset, and informs the TM of any changes which could impact ECM deployment, such as:

- Equipment Limitations/failure
  - e.g. port side jammer antenna failed, chaff launcher malfunctioned, etc.

- Decoy Stock Level
  - e.g. number of chaff/IR rounds or rubber ducks remaining, etc.

- Interference
  - e.g. chaff obstructing jammer's line of sight, etc.

The DM also passes along operating constraints to each device as indicated by the TM. The constraints include:

- Temporal (EMCON)
  - complete non-radiation for a specified period of time

- Frequency
  - non-radiation at certain frequencies

- Spatial
  - non-radiation or decoy deployment in a specific sector or bearing

- Techniques
  - non deployment of specific ECM techniques or decoys

3.2 Effectiveness Assessment

The EA module within the NEWCP compares the measured response of a threat to countermeasures with the expected response. If they match, then it gives confidence to the EW deployment module that the current ECM deployment is being effective. On the other hand, if the comparison differs, then it is a indication the countermeasures may not be having an adverse affect on the threat, requiring a change in technique or parameter. Figure 5 provides a functional illustration of the EA module, showing the two primary inputs, the blackboard and knowledge base, and the output which is fed to the EW deployment module via the blackboard. The principal output states of the EA module are: i) ECM is effective, ii) ECM is ineffective, or iii) unknown, along with a confidence level, expressed in percentage from 0-100, regarding each assessment.

The 'ECM is effective' outcome, which indicates the threat is responding to the countermeasures as expected, is based upon the detection or measurement of one or more of the following events:

- radar mode change
- trajectory deviation
- chaff cloud reflections
- 'jogs
- kill

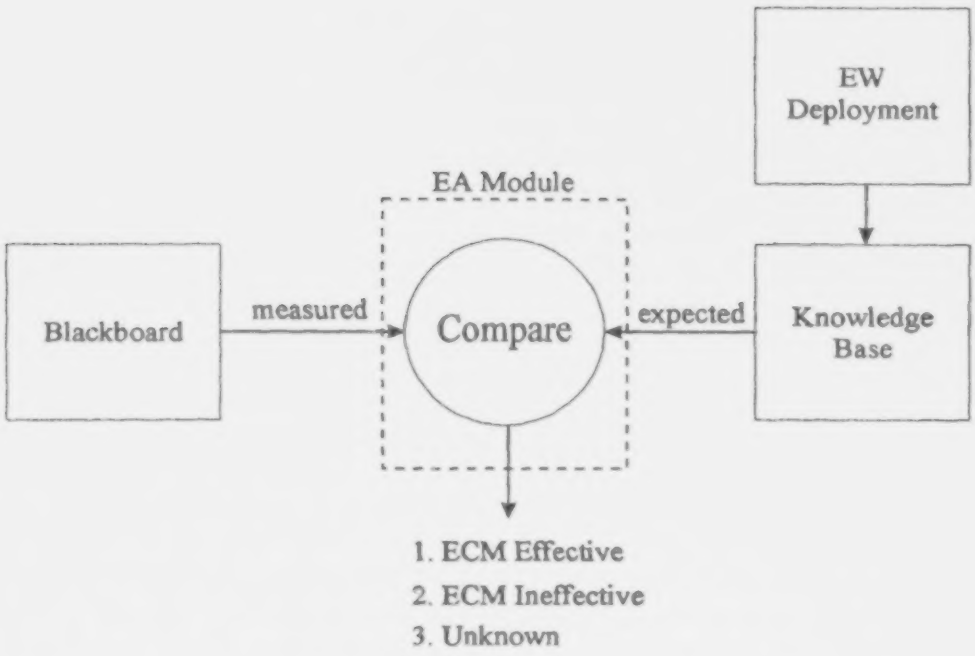


Figure 5. Effectiveness assessment functional layout.

Refer to the 'Effectiveness of Countermeasures' report, of the 'Integration of Electronic Warfare Assets on Maritime Platforms - Phase 1' project, for a detailed elaboration on each of these events and the sensors which could be used to measure them. The table below summarizes the principal role each type of sensor can play in achieving effectiveness assessment. Note that some of these sensors can support the EA function in a secondary role, such as the human observing a trajectory deviation. The accuracy would be poor and the range limited, however, if it is necessary, the operator could confirm heading shifts that would be useful to the NEWCP.

Sensor	radar mode change	trajectory deviation	chaff cloud reflections	jogs	kill
ESM	✓		✓	✓	✓
Radar		✓		✓	✓
IRST		✓			✓
HADF		✓	✓		✓
Human observer					✓

Associated with the measurement process of each event is a certain amount of uncertainty which has to be dealt with in the appropriate manner. An error in EA may lead to the execution of ineffective countermeasures, resulting possibly in a beaconing of the threat towards own ship. The source of errors, as described in the previous section, may originate from: the environment, sensors, sensor data fusion process, inferencing or reasoning that occurs in the EWTSA, and/or knowledge base. Software algorithms implemented in the EA module will require uncertainty management systems (UMS) to deal with the various forms of uncertainty, including the different versions of Dempster Shafer and fuzzy logic. Both UMS' have their advantages and disadvantages, in terms of speed, completeness, accuracy, and flexibility, and it is possible the NEWCP may use a hybridized version of both for optimal processing.

EA functionality, similar to the EW deployment module, will be distributed amongst the four managers, described in the previous section, including: EW battle manager, EW engagement manager, EW tactical manager, and device manager. The matrix below lists the managers and their associated EA events:

Battle Manager - Kill

Engagement Manager - Trajectory deviations

Tactical Manager - Radar mode changes, jogs, chaff reflections

Device Manager - N/A

The EW battle manager ultimately decides if the threat has been defeated by softkill, hence, it makes use of the EA function which reports on a kill status. The engagement manager is responsible for a single threat, ensuring the current tactic is causing the missile to deviate in trajectory and miss own ship. The tactical manager is responsible for executing a tightly coupled series of ECM techniques, to disturb the threat system so that it results in a radar mode change, jog, or chaff reflections. The device manager does not require EA information. Since jogs have to be measured and reported to the jammer almost instantaneously, it is not likely this function would reside within the NEWCP given the speed constraints. As discussed in the 'Origin of Deployment Control' report of 'The integration of EW assets on maritime platforms - Phase 1' project, the RAMSES jammer already has a jog detection capability, and any additional jog circuitry would have to be implemented in a dedicated sensor which reports the jog event directly to the jammer's internal logic circuitry.

3.3 EW Tactical Situation Assessment

3.3.1 Introduction

The purpose of this section of the report is describe the tactical situation assessment functionality that will reside within the NEWCP. In addition, the relationship between this function and other functions / components of the CPF combat system will be addressed. It should be immediately made clear that within the CPF, tactical situation assessment functionality will be distributed across multiple agents. For our purposes, there are two agents of interest: the CCS and the NEWCP. It is intended that the NEWCP focus its situation assessment functions in the area of EW, while the CCS shall retain responsibility for generating a higher level tactical picture that supports all combat functions of the CPF.

Accordingly, the issue of the distribution of tactical situation assessment functionality between the CCS and the NEWCP will be addressed in this section. In support of this objective, data flow between the TSA function of the NEWCP and the CCS will be defined. Other issues to be addressed in this section include the relationship between the NEWCP's TSA function and other NEWCP functions such as effectiveness assessment and EW deployment and control. Once more, relevant data flow will be specified.

A fundamental assumption governing the elaboration of NEWCP tactical situation assessment functionality is that the NEWCP will be responsible for those aspects of tactical situation assessment functionality that specifically relate to EW activities and their possible interactions with other ship operations. Hence the acronym EWTSA (Electronic Warfare Tactical Situation Assessment) will be used.

The tactical situation assessment function can be described in terms of the generation of

hypotheses descriptive of the combat environment, based upon the domain model created by the sensor data fusion function, to support resource allocation decisions. In the specific context of interest (i.e. the CPF), tactical situation assessment function supports decisions concerning allocation of such resources as sensors, hardkill weapons, and softkill weapons.

In the following section, an overview will be provided of the principal functions of the tactical situation assessment function. Each of these functions will first be described in general terms and then in terms of the specific context of the NEWCP.

The boundary between the SDF function and the TSA function can be unclear in that it is a matter of definition and hence somewhat arbitrary. A definition of this boundary, strictly for the purposes of this report, will be provided as follows: The open literature identifies three basic levels of data fusion processing:

1. Level 1: The alignment, association, correlation of sensor measurements and their use in the derivation of target tracks and target identity;

2. Level 2: The assessment of meaning or patterns in the order of battle (contextual interpretation of distribution of forces;

3. Level 3: Threat assessment including intentionality, and lethality of enemy forces.

For the purposes of this report, the SDF function shall be considered to incorporate the functionality associated with Level 1 while Levels 2 and 3 will considered to be part of the TSA function. Attention will now be turned to the elaboration of TSA functionality in terms of fundamental elements of the combat environment to which TSA is relevant. Functionality will first be described generally and then within the specific context of EWTSA.

3.3.2 EW Tactical Situation Assessment

Tactical situation assessment functionality can be described in terms of categories of assessments that relate to various aspects of the overall combat environment. More specifically, tactical situation assessments can be made concerning the disposition of the threat, the disposition of defence assets, as well as the environment.

Threat Assessment

The tactical situation assessment function is responsible for integrating low level information, provided primarily (though not exclusively) by sensors via the SDF function, in order to produce higher level global situation hypotheses about the disposition of the

threat. Although the SDF function provides target kinematics and identity, higher level assessments are required in order to support the command decision and evaluation functions (e.g. EW effectiveness assessment, EW deployment and control) of the combat system in question. Primary among these is an assessment of the enemy's probable courses of action. In addition, an assessment of the capability of the enemy to threaten the Force is required.

To complement assessments concerning enemy intentions and capabilities, an appraisal of threat vulnerabilities is required, particularly in relation of the threat's ability to carry out its intention.

Threats to the Force can be classified into one of three categories: direct, indirect, or potential. Direct threats are those that have been detected by sensors and their behaviour indicates that they are currently in the act of attacking the Force. Indirect threats are those that are expected to appear based upon intelligence information concerning platforms that have already been detected and identified by Force sensors. Finally, the appearance of potential threat is based upon predictions supported by intelligence information alone.

The high level purpose associated with performing tactical situation assessment related to the threat is to generate as complete a characterization as possible of threat intentions, capabilities, vulnerabilities, and possible attack scenarios. Possible attack scenarios can be characterized in terms of timing of an attack, number of units involved, likely targets, etc.

Within the specific context of the NEWCP, the following target assessments are made based on EW information:

- Inferred weapons behaviour associated with launch platforms detected in the environment;
- Predicted threat flight sequences (e.g. manoeuvres, pop-ups, dives, etc.);
- Predicted threat sequence of guidance mode sequences (e.g. active radar, passive IR, ARM, etc.);
- Threat ECCM characteristics;
- Characterization of threat vulnerabilities to ECM;

- Threat ECM strategy / tactics;

- Characterization of threat trajectory changes in support of EW effectiveness assessments;

- Characterization of threat radar mode changes in support of EW effectiveness assessment;

- Characterization of chaff cloud reflections in support of EW effectiveness assessment.

Defence Assessment

In order to support the command decision and evaluation functions associated with a combat system, knowledge is required concerning the current disposition of Force assets. Some of this knowledge is static in nature (e.g. maximum range capability of a weapon system) while other knowledge is dynamic (e.g. available / busy indication for a Force jammer asset).

A defence assessment capability is required in order to provide the command decision and evaluation functions with a characterization of the ability of the Force to respond to the attack scenarios that have been postulated as a result of the execution of threat assessment activities (as described above).

An integral component of a defence assessment capability will be the ability to estimate the coverage provided by Force weapons and sensors. This information is vital to the command decision function in the formulation of defence responses. A related requirement involves the requirement to support fratricide and interference prediction. A characterization of the positions and intended courses of Force assets is needed to allow the command decision function to prevent the implementation of defence responses that place Force platforms at risk. Similarly, the command decision and evaluation functions require a characterization of possible spatial and spectral interference problems that might arise from candidate defence actions.

Within the specific context of the NEWCP, the following target assessments are made based on EW information:

- Characterization of ownship / Force ECM asset position;

- Characterization of operating states of ownship / Force ECM assets (including parameters such as frequency of operation, spatial sector into which asset is radiating, etc.);

- Characterization of ownship / Force ECM asset stock level;

- Characterization of performance limits of ownship / Force ECM assets (e.g. maximum effective range, blind zones, etc.).

Environmental Assessment

A complete tactical situation assessment function must provide the command decision and evaluation functions with environmental assessments. The performance of certain sensors and weapons can be profoundly influenced by environmental effects. For example, certain sea states can influence the reliability of jog detection measurements performed against sea skimming missile whereas wind will influence the performance of chaff.

Within the specific context of the NEWCP, the following environmental assessments are made related to EW engagements:

- sea state (supports prediction of effects of multipath);

Note that other meteorological information is of interest to the NEWCP. However, it is anticipated that wind direction, wind speed, and precipitation information will be supplied by the CCS.

While it may not be explicitly stated in the preceding paragraphs, the assessments provided by the TSA function do involve a characterization of the interactions between elements of the combat environment. Examples of such interactions, that will be characterized by the TSA function include (representative list):

→ The knowledge that Force radars are radiating (defence assessment) can be combined with the knowledge about the weapon complements of platforms in the environment (threat assessment) to conclude that an ARM missile attack is likely;

→ A knowledge of the emitter characteristics of an incoming ASM (threat assessment) can be combined with a knowledge of ownship jammer power output (defence assessment) in order to estimate the range / time at which the incoming threat will achieve burnthrough;

→ A knowledge that the combat environment is foggy can be combined with a knowledge of the characteristics of a Force IR sensor to conclude that the sensor cannot be expected to detect targets beyond a certain range.

There a variety of generic model types that the EWTSA function will use in the generation of tactical situation assessments. *Structural models* define the relationships between measured target attributes (e.g. RF emissions) and other features that are inferred from such measurements. For example, it might be possible to infer the presence of a particular threat EPM characteristic based on the characteristics of the targets RF emissions. *Behavioral models* produce inferences about future events based on past threat activities. For example, if a brief illumination is received from a threat that is known to be a weapons platform, it can be inferred that a missile launch from that platform is imminent.

It is worthy to note that many tactical situation assessments will be based on heuristics - rules of thumb (i.e. IF...THEN...ELSE constructs) that represent knowledge and intelligence culled from a variety of sources over a period of time.

Finally, the issue of how the EW tactical picture, generated by the EWTSA function, is communicated to the operator should be addressed. It is envisaged that a display of the form presented in Figure 3 will provide the operator with visibility into the tactical picture as derived by the EWTSA function.

3.3.3 Relationship of EWTSA to Other Functions / Agents

The purpose of this sub-section is to describe the relationship of the EWTSA function to both the sensor data fusion function (which is the principal source of input data to EWTSA) and the command decision and evaluation functions which are supported by EWTSA.

As indicated earlier, the SDF function supports the EWTSA function by providing it with a model of a subset of the combat environment. The subset in question consists primarily of threat and environmental information. Most information concerning defence assets and missions goals is provided from sources other than the SDF function.

The model provided to EWTSA is basically expressed in terms of target positions and speeds, target identity, and environmental measurements. In addition, the EWTSA will require that the SDF function provides detailed information characterizing the emissions characteristics of those targets that are emitting (or reflecting) RF energy. Many of the high level assessments executed by the EWTSA function will require such information. For example, the EWTSA function supports the EW effectiveness assessment function (as described below). Accordingly, EWTSA must provide this function with seeker jog measurement data, radar mode change data, and chaff

reflection data so that the appropriate assessments can be made.

The model that the SDF function provides to the EWTSA function is characterized by uncertainties that arise primarily from limited sensor accuracy and coverage. As a result of this uncertainty, the SDF function may provide multiple hypotheses concerning the elements of the situation model (e.g. target locations, identities, behaviours, etc.). The tactical situation assessment function then refines these hypotheses using doctrinal templates and probabilistic inference to select an appropriate subset to forward to the EW command decision and evaluation functions.

An important aspect of the relationship between the EWTSA function and the SDF function is the requirement for the former function to be capable of querying the latter function to search for data that might support candidate hypotheses under consideration. This is a goal-driven process in the sense that the EWTSA is attempting to minimize ambiguity in its characterization of the tactical situation.

Queries of the SDF by the TSA function can be implemented through the mechanism of sensor cues. Sensor cuing request allows the EWTSA function to control the operations of sensors to allow for resolution of ambiguity with respect to level of threat posed by an air track. In addition, sensor cuing allows the EWTSA to attempt to reinforce the general hypotheses that it is developing about the combat environment.

As alluded to above, the primary objective of the EWTSA is to support the command decision and evaluation functions related to EW activity. More specifically, the EWTSA supports both the EW effectiveness assessment function as well as the EW deployment and control function. In general terms, the output that the EWTSA function provides to these two functions consists in part of the descriptors needed to define the situation at the level of abstraction necessary to support effectiveness assessments and EW deployment and control decisions. Associated with each of these descriptors will be some associated measure of certainty.

In more specific terms, the EWTSA function will provide the EW effectiveness assessment and EW deployment and control functions with a range of information including, but not limited to the specific items listed in the final paragraph of each of the above sections describing target assessment, defence assessment, and environmental assessment.

Despite the fact that the EWTSA function derives a tactical picture based specifically on EW information, some aspects of this EW tactical picture are of interest to other combat system agents. In particular, the EWTSA provides information to the CCS to support that agent's function. Most of the information provided by the EWTSA to the CCS will be the same as that provided to the EW effectiveness assessment and EW deployment and control functions. For

example, any inferences that the EWTSA function makes with respect to threat weapons activity is of definite interest to the CCS; if EWTSA processing indicates that a missile is imminent, the CCS will need to know this information.

The prevention of fratricide and interference are critical functions within the context of naval air defence. The EWTSA will support the execution of these functions through the provision of relevant data to the CCS. If EWTSA processing in this area is relatively unsophisticated, data of interest can include the position and operating states of Force ECM assets, frequencies of operation of ECM assets, etc. For more sophisticated EWTSA processing relevant to interference and fratricide prediction, the EWTSA might provide specific predictions concerning interference and fratricide events.

Just as the EWTSA function is capable of querying the SDF function for more information to support its hypothesis generation, the CCS, the EW deployment and control function, and the EW effectiveness assessment function are capable of querying the EWTSA for more information about the tactical situation. A likely consequence of such requests is that the EWTSA function will query the SDF to provide information to support the requested assessment.

3.3.4 Division of TSA responsibility between CCS and NEWCP

As indicated earlier, it is envisioned that TSA function in the CPF will be distributed across multiple agents including, but not necessarily limited to, the CCS and the NEWCP. In the material provided above, an attempt has been made to elaborate on the TSA assessments that will be performed by the NEWCP's EWTSA function. The EWTSA activities of the NEWCP are intended to complement the TSA functions of the CCS. A representative list of TSA functions performed by the CCS are provided in the following list. This list of assessment activities is divided into three categories: threat assessment, defence assessment, and environmental assessment. These are the same categories by which EWTSA functionality has already been elaborated.

Target Assessment

- Track position, velocity;
- Threat ranking;
- Order of Battle

Defence Assessment

- Ownship / Force members position, velocity;

- Performance limits associated with ownship sensors and hardkill weapons;
- Operating parameters (e.g. frequency of operation) of ownship / Force weapons and sensors;
- Stock level of hardkill munitions.

Environmental Assessment

- wind speed;
- wind direction;
- precipitation measurements.

Figure 6 provides a schematic representation of the way in which EWTSA assessments serve to complement the TSA activities executed by the CCS. It can be seen that the NEWCP essentially "overlays" or superposes its tactical situation assessments over those generated by the CCS.

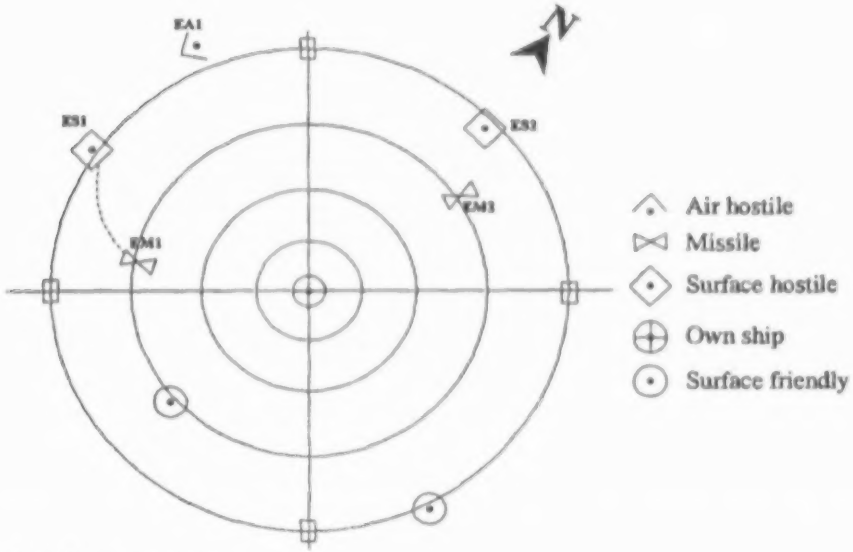
3.4 NEWCP Knowledge Base

3.4.1 Introduction

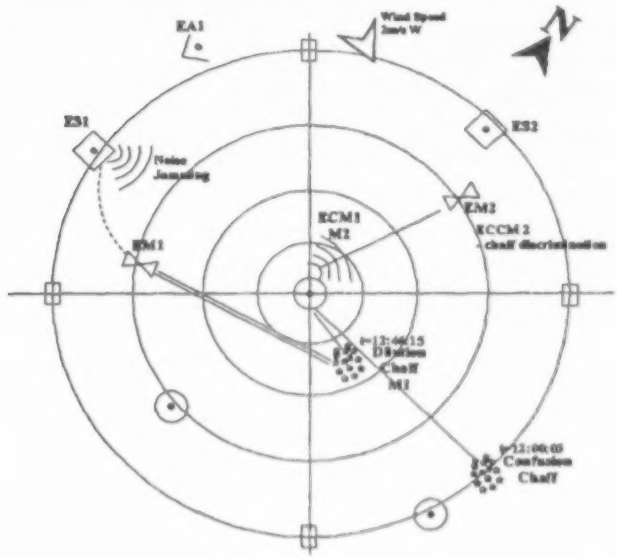
The purpose of this section of the report is to describe the knowledge base that will reside within the NEWCP. In addition, the relationship between this knowledge base and other functions of the NEWCP will be described.

Stated simply, the knowledge base associated with the NEWCP contains a set of facts and rules that express domain knowledge. This is static knowledge in the sense that it does not represent knowledge about the evolution of any particular tactical situation. For example, the knowledge base will contain the expected response of threat X to the application of noise jamming whereas it will not contain the current state of ownship EW assets. The latter item describes the state of a particular engagement, not domain knowledge relevant to EW engagements.

Given the relatively broad scope of functionality that is to be present in the NEWCP, many types of information will be present in the knowledge base. Representative examples of information to be found in the knowledge base will be provided later in this section. Before providing an indication of the information to be found in the knowledge base, some background information concerning the structural relationship of the knowledge base to other elements of the NEWCP is required. As is discussed elsewhere in this report, a blackboard model is proposed for use within the NEWCP. J.R. Altoft provides the following description of the blackboard model:



a) CCS tactical situation assessment.



b) CCS + NEWCP tactical situation assessment

Figure 6 CCS and EW Tactical Situation Assessments.

> "A blackboard system is generally described as having three basic components: the shared data structure known as the blackboard, the knowledge sources, and the control structure. A description of the current problem, any partial solutions, alternative interpretations, etc., are maintained on the blackboard. The problem-independent domain knowledge is embedded in the knowledge sources, known as specialists. The control structure arbitrates the specialists' access to the blackboard."

The knowledge base to be discussed in the remainder of this section of the report represents the problem-independent domain knowledge referred to in the above definition. Within the context of the NEWCP, the specialists are the principal functional agents, primarily the effectiveness assessment function, the EW deployment and control function, and the EW tactical situation assessment function (EWTSA).

It is important to distinguish between the blackboard model and the blackboard structure itself. Although a variety of agent (specialists using Altoft's terminology) use the blackboard, they should not be considered as part of the blackboard data structure. However, they do use the blackboard in accordance with the principles elaborated in the blackboard model definition provided above.

In the following section, representative knowledge embedded within the three principal NEWCP functional components (effectiveness assessment, EW deployment and control, and EWTSA) is provided.

3.4.2 Specification of NEWCP Knowledge Base

The purpose of this sub-section is to describe the information that will be present with the knowledge base of the NEWCP. As indicated above, problem-independent domain knowledge will be used by different agents (specialists) within the context of the NEWCP blackboard concept. The knowledge base associated with the effectiveness assessment, EW deployment and control, and EWTSA.

The knowledge embedded within NEWCP agents can be classified according to whether it is declarative knowledge or procedural knowledge. Declarative knowledge describes facts whereas procedural knowledge describes temporal event sequences. The fact that clutter introduces ambiguity into jog detection measurements is an example of declarative knowledge whereas the steps to take in the prosecution of a certain missile threat is an example of procedural knowledge.

It is to be noted that the knowledge present in the knowledge base has its origin in a variety of sources. Some knowledge arises from historical tactical experience (e.g. which ECM techniques have proved effective against threat X in past engagements). Other knowledge can be derived

as the result of sea trials and / or simulation. Knowledge can also be generated as the result of theoretical analysis (e.g. effects of sea-state upon jog detection performance). Finally knowledge can be acquired through the execution of intelligence activities.

Effectiveness Assessment Knowledge Base

- Specification of jog responses; this provides the effectiveness assessment function with information concerning expected threat jog response to specific countermeasures;

- Specification of radar mode changes; this provides the effectiveness assessment function with information concerning expected threat radar mode changes in response to specific countermeasures;

- Specification of trajectory deviations; this provides the effectiveness assessment function with information concerning expected threat trajectory deviations in response to specific countermeasures;

- Specification of chaff reflections; this provides the effectiveness assessment function with information concerning chaff reflection measurements that might be expected in response to specific countermeasures;

- Specification of lost / kill criteria; the NEWCP will support the CCS in determining whether a threat is no longer capable of endangering Force assets. For example, the NEWCP may have embedded within it specialized EW knowledge descriptive of the field of view of a threat seeker that might be used in determining whether a threat still poses a threat to the Force.

EW Deployment and Control Knowledge Base

- A mapping [threat characteristics → ECM response] specifying specific (surgical) ECM techniques (and associated parameters) to be employed when threat identity and other attributes are well known;

- A mapping [threat characteristics → ECM response] specifying general ECM techniques (and associated parameters) to be employed when limited threat identity and other information is available;

- Specification of highly robust ECM techniques to be applied when no significant threat information is available;

- Characterization of the effects of environmental parameters (e.g. wind, fog) on the deployment / performance of countermeasures.

- Detailed specification of ECM capabilities / performance, e.g.:

  * chaff launcher directions;
  * chaff / rubber duck RCS;
  * IR flare radiance;
  * On-board jammer and AOD output power;
  * Deployment time overhead of ECM assets;
  * Blind zones;
  * etc.

Note that the knowledge embedded in the items above contains information about sequences of ECM activities, ECM technique spectral, spatial, temporal information, predicted effectiveness, etc.

Tactical Situation Assessment Knowledge Base

- Ship sensor capabilities and limitations (e.g. maximum range, blind zones, etc);

- ECM asset capabilities and limitations (e.g. maximum range, spectral limitations, etc.;

- Ship combat role (e.g. point defence, area defence, high level tactics);

- Profiles of anticipated threat flight sequences (e.g. pop-ups, dives, etc.);

- Profiles of anticipated threat guidance mode sequences (e.g. expected profile of active radar seeker transition from search → acquisition → track);

- Profiles of expected threat weapons launch activities (i.e. a mapping establishing what enemy launch platform behaviours are expected to precede missile launch;

- Threat EPM characteristics;

- Threat ECM characteristics and behaviours;

- Characterization of threat vulnerabilities to ECM;

- Characterization of the effects of clutter on jog detection measurements;

- Characterization of the effect of precipitation on the performance of sensors (e.g. the fact that fog degrades the performance of an IR sensor;

- Characterization of the effect of ducting on sensor performance;

Note that some of the items present in the EWTSA list may also be relevant to other agents; for example, the fact that fog degrades IR sensor performance may not only be relevant to EWTSA, it is also knowledge that may be important to the effectiveness assessment function. To avoid repetition, specific items of knowledge are only presented in one of the three lists.

3.5 Blackboard

The blackboard (BB), which is also referred to as the opportunistic planner in expert system literature, is fundamentally a global data base which allows disparate data to be dynamically stored and retrieved asynchronously by various sources, known as knowledge sources (KS). The data in the BB may comprise simple facts or partial solutions to the overall EW softkill problem, which can be retrieved, modified, and restored by the individual KS'. The data is gradually combined at different KS levels, leading to an incremental generation of the final EW solution. Only one KS can access the BB at any given time, hence, a mediator is required in cases where more than one KS requires the use of the BB at the same time. The mechanism used to resolve blackboard conflicts is called the scheduler and control function (CF). The CF, in addition to mediating, ensures that the data to all KS' is current and complete, and reported in the proper manner.

In regard to the NEWCP, the KS' comprise the EWTSA, EW deployment (including the four hierarchical managers), effectiveness assessment, knowledge base, and blackboard scheduler and control modules. The BB represents the primary entry point of all data originating from outside the NEWCP, including the CCS, and sensor data fusion processor. Likewise, all data and instructions leaving the NEWCP is directed through the blackboard. Refer to figure 7 for a functional diagram of a representative blackboard designed for the NEWCP. The blackboard control function defines which data can be modified or interrogated by specific knowledge sources. Also, the CF determines the relative priorities of each KS regarding access to and overall control of the BB at any given time. For example, the EWTSA may be the only module which can modify EWTSA data, while all other knowledge sources can access this information for their specific requirements. The control function is a dynamic process, which can be altered any time to meet new NEWCP requirements, such as changing the priority ratings of the KS' or

changing the protocol regarding accessibility to data. This alteration, which gives full flexibility to the overall blackboard paradigm, can be initiated by the EW operator through the NEWCP operator machine interface (OMI).

Figure 8 depicts an example of a more detailed breakdown of the blackboard regarding CCS data, real-time data, effectiveness assessment data, and knowledge base data. Each box within the KS represents a unique address containing specific data. For example, under the real time data entry, it is indicated that contact number 1 is a SS-N-3 missile operating in lock-on mode. It has a RF of 9 GHz, a pulse width of 1 microsecond, and a pulse repetition interval of 1 ms. The missile is located at an azimuth reading of 35 degrees and elevation of 5 degrees. According to the stored EA data, the current ECM has caused the seeker to experience a mode change, from lock-on to fine search. No trajectory deviations nor chaff cloud reflections were registered, however some jogs were detected, indicating a possible successful ECM deployment.

The figure provides an example of the types of data that may be stored onto the blackboard. Architectural considerations may preclude some of this data from residing on the blackboard including speed constraints, databus limitations, etc. The blackboard scheduler and control function will be complex, performing multiple tasks in real-time. The final design will likely have to be based upon a parallel architecture, so that the performance of the NEWCP is operationally acceptable.

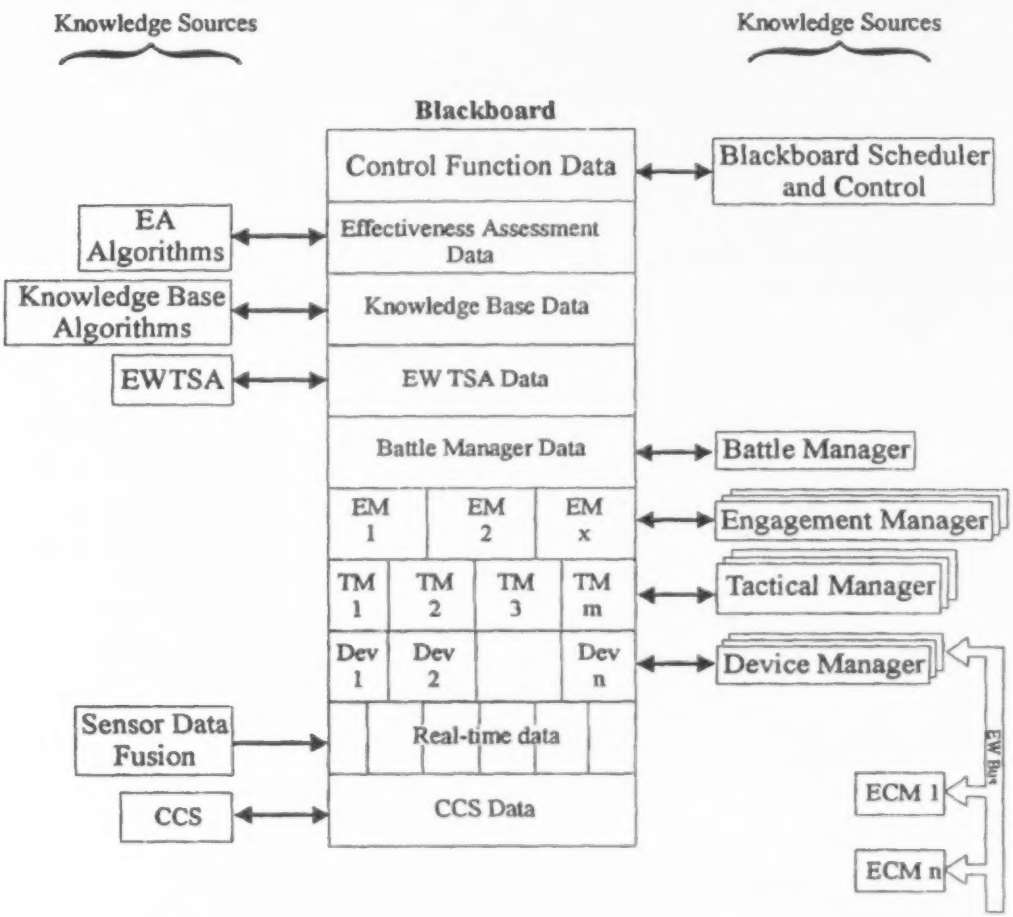


Figure 7. Sample blackboard paradigm for the NEWCP.

CCS to NEWCP Data

Priority	Constraints	Ship's Doctrine	CCS TSA	Sensor Status	EW coordination	.....
Contacts 1) 1 2) 3 3) 5	EMCON	Protect fleet		- Radar 1 inoperable	fleet cooperative jamming	....

Real Time Data

Contact No.	ID	Radar Mode	RF	PW	PRI	Az	El	.....
1	SS-N-3	Lock-on	9	1	1	35	5	.....
2	Exocet	Lock-on	12	2	2	124	2	.....
.....								

Effectiveness Assessment Data

Contact No.	Radar Mode Change	Trajectory Deviation	Chaff Reflections	Jogs	Kill
1	track - search (f)	no	no	yes	no
2	no	no	yes	no	no
.....					

Knowledge Base Data

Contact No.	Associated Emitters	ECCM	Pre-programmed Trajectories	Past successful ECM	.....
1	- Big Bulge	Chaff ECCM	no	fast RGPO	
2	-	HOJ	3 way points	chaff	
.....					

Figure 8. Sample data structure within the blackboard.

4.0 EWCP Phase II Work

4.1 Statement of Work

This section describes the statement of work (SOW) for Phase II of the 'Integration of Electronic Warfare Assets on Maritime Platforms' project. The SOW includes a work breakdown, schedule and cost for all milestones and deliverables. Phase II comprises ten tasks:

i) Program management,
ii) Finalize concepts from Phase 1,
iii) EWCP functional design,
iv) Interim report
v) Software implementation of individual algorithms,
vi) Integrate and test,
vii) Simulation tools preparation,
viii) Evaluate EWCP,
ix) Real-time implementation issues, and
x) Final report.

Task 1 Program management

This task will be performed by the prime contractor who will have the responsibility of planning and controlling the overall project, including: i) organizing meetings and reviews with DREO and other DND agencies, ii) coordinating the activities of the sub-contractor, iii) generating monthly progress reports, and iv) producing a master detailed schedule from which all deliverables will be planned and executed.

Task 2 Finalize concepts from Phase 1

The purpose of this task is to review and adapt the concepts established in Phase 1 of the naval EWCP program to specific ship and threat environments in which the EWCP is intended to operate. The contractor shall, with input from the Scientific Authority (SA), specify the shipborne sensors, EW weapons, CCS environment, and sensor data fusion (SDF) process which will form the basis for a final EWCP functional design. The operational characteristics of each of the selected assets will be defined at the level of detail sufficient to support EWCP development. Where necessary, aspects of EWCP concepts will be modified to correspond with the established operating environment. For example, an EA technique identified in Phase 1 may be disregarded if the required sensor is not selected as part of the baseline suite. Note a modular design approach will be taken for the EWCP to accommodate system expansion in the future.

Task 3 EWCP functional design

The contractor shall design the individual functions/algorithms comprising the EWCP, including: EW deployment and its defence layer managers (EW battle/engagement/tactical/device), EW threat situation assessment (TSA), ECM effectiveness assessment (EA), blackboard (BB), knowledge base, and the central processing functions responsible for the overall operation of the EWCP, such as integrating/coordinating the various functionalities within the EWCP. Refer to figure 1 of section 3 for a conceptual illustration of the EWCP, and the accompanying text for a description of the concepts behind each function.

For each algorithm, the Dempster-Shafer, Fuzzy logic, or any other uncertainty management system (UMS) deemed appropriate, will be examined to determine their suitability based upon specific performance requirements such as timeliness, accuracy, completeness, etc. Once a choice has been made, the algorithms will be written in detail regarding the relevant functions of the EWCP. As well, in this task, the contractor shall specify in detail the interfaces between the EWCP and CCS/SDF and the architecture necessary to support the interaction between the various elements.

Task 4 Interim Report

The contractor shall write an interim report, based on the results obtained in task 3. The report will describe the algorithms and their interactions with other sub-functions of EWCP, in sufficient detail to support software implementation. The algorithms will be approved by the SA.

Task 5 Software implementation and testing of individual algorithms

The focus of this task is to prove the concepts of each algorithm specified in task 3, by performing the following prototyping activities: implement each algorithm in software, execute test runs with the appropriate stimulants applied, analyze the simulation results, and where necessary, modify the algorithm to improve its performance. The analysis will include the comparison of measured results to expected results. The test matrix to support this activity will be established and approved by the SA before testing commences. The test matrix will address performance issues such as accuracy and completeness.

The selection of software tools to support this activity is addressed in task 8, which will be performed in parallel with tasks 5, 6 and 7.

Task 6 Integrate and test

The contractor shall integrate the individual algorithms and functions of the EWCP through the blackboard and its scheduler/controller. A test matrix will be written and followed which defines the manner in which interaction between each algorithm is evaluated, addressing performance

issues such as functional compatibility (e.g. ensuring fuzzy logic in one module correctly interprets a Dempster-Shafer result), communication protocol, efficiency, completeness, etc. Where necessary, changes to the various algorithms and controller will be made to improve overall system performance.

Task 7 EWCP Evaluation

This task is concerned with testing the overall operation of the EWCP in a simulated maritime environment. The contractor shall perform simulation runs to help determine the survivability improvement of the ship by comparing runs with and without the EWCP. The contractor shall do the following: i) establish a comprehensive test matrix, to evaluate ship survivability with and without an EWCP, for approval by the SA, ii) define the ship's baseline EW suite performance (based on the assets defined in task 1) without the EWCP - to be approved by the SA, iii) perform simulation testing, and iv) analyze the simulation results and report on the conclusions. Testing will involve a sensitivity analysis to explore such issues as ECM deployment time, EWCP overhead processing time, sensor response times, etc., to determine their impact on overall ship defence. Also, the simulation runs will help determine where improvements could be made to increase EWCP effectiveness.

Task 8 Simulation Tools Preparation

The contractor shall select the appropriate tools for testing the overall operation of the EWCP (note this task will be done in support of tasks 5, 6, and 7). Limited modifications or enhancements shall be made to existing simulation models to facilitate the integration of the EWCP algorithms - this activity will be approved by the SA.

The preparation of the simulation models will address the three levels of testing: i) to evaluate individual algorithms (task 5), ii) test the interaction of the algorithms within the EWCP (task 6), and iii) test the overall operation of the EWCP in a realistic maritime environment (task 7).

Task 9 Real-time implementation issues

The contractor shall investigate real-time implementation issues, such as making use of dedicated parallel processors and specialized supporting hardware to streamline the algorithms within the EWCP, so that the EWCP can respond in the appropriate time against multiple threats in the pre-defined scenario. The scenario and sensors specified in Task 1(above) will further refine the real-time requirements in terms of the time available to respond to the threat. Also, the ship's overall data bus architecture will be examined to determine the best means of implementing the EWCP, and passing data back and forth between the CCS, sensor data fusion module, the sensors themselves, and EW weapons. The contractor will study the issues of the impact of the selection of a particular software language/compiler on real-time performance. The contractor will identify and study different methodologies for estimating EWCP real-time performance capabilities.

Task 10 Final Report

A final report will be written based on the work performed in the previous tasks.

4.2 Project Schedule

Phase II of the EWCP project is expected to be performed over a twenty-four month period. Figure 9 depicts the project schedule, indicating the beginning and duration of each task, expressed in months. The task duration is commensurate with the level of effort required to complete each one, assuming an anticipated average man-loading of two full time intermediate to senior engineers. The schedule also depicts the inter-relation or time dependence of each task throughout the program. An interim report will be produced in task 4, while a final report will be written at the end of the project. A number of task items throughout the program will be subject to approval by the Scientific Authority, and are articulated in the SOW above.

4.3 Project Cost

This section provides a rough order of magnitude (ROM) price estimate associated with phase II of "The Integration of Electronic Warfare Assets on Maritime Platforms". Table 4-1 indicates the percentage of work done for each task per year and the total ROM price. The rates for 1994 are based on the quotes presented in the price proposal for Phase I of this project. The '95 and '96 rates assume an escalation of 3%. The average rates are a composite of both Lockheed Canada and Thomson-CSF rates and the listed ROM price is based on a time-phased estimate. The total price is estimated to be $623,219, GST excluded, based upon a contracting arrangement of firm hourly rates to a limitation of expenditure. These ROM prices assume a contract award date of mid '94. It is anticipated the final price will be established once the Phase II SOW is finalized.

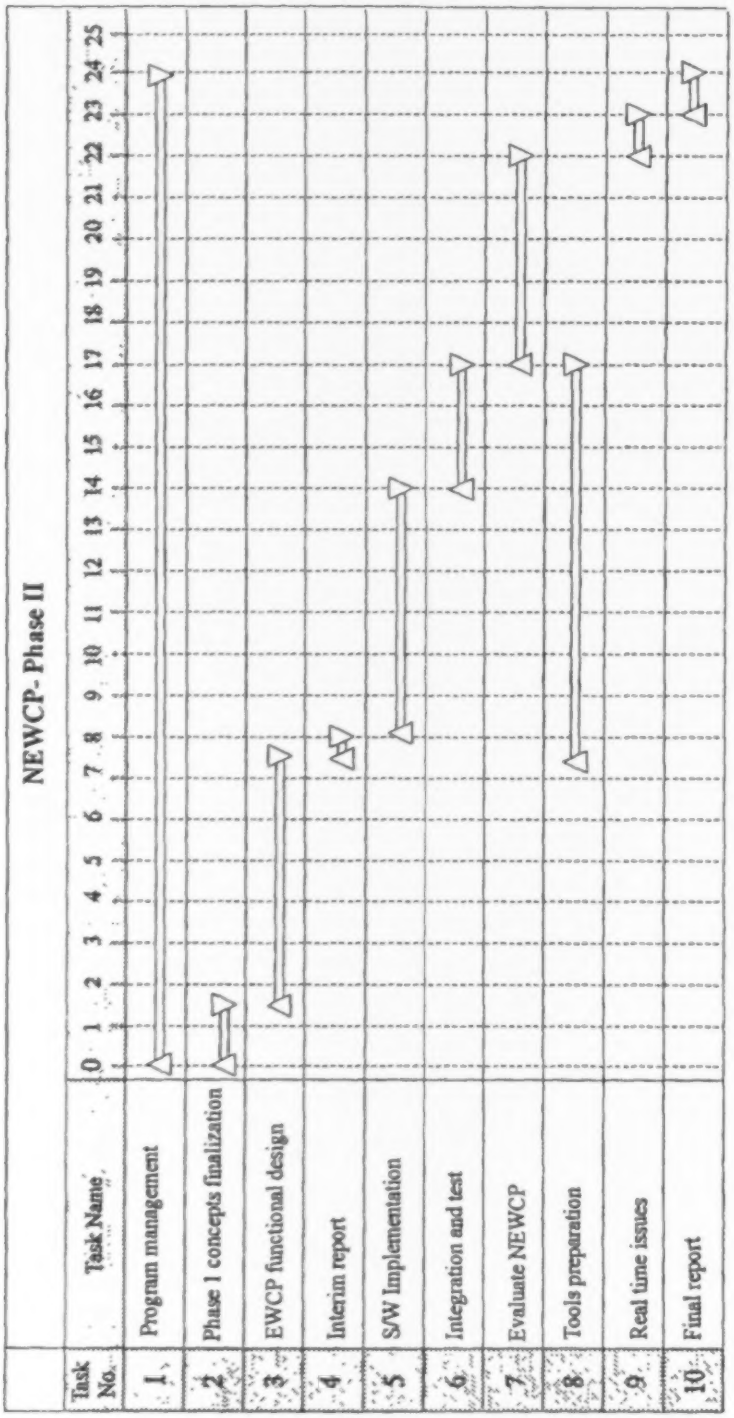

NEWCP- Phase II
Task No.
Task Name
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
1 Program management
2 Phase 1 concepts finalization
3 EWCP functional design
4 Interim report
5 S/W Implementation
6 Integration and test
7 Evaluate NEWCP
8 Tools preparation
9 Real time issues
10 Final report

Figure 9. Project schedule for Phase II of EWCP

Table 4-1. EWCP-Phase II ROM price.

Task No.	Description	% done in 1994	% done in 1995	% done in 1996	ROM Price
1	Program management	25	50	25	48,000
2	Phase 1 concepts finalization	100	0	0	25,000
3	EWCP functional design	40	60	0	150,000
4	Interim report	100	0	0	10,000
5	Software implementation	0	100	0	135,000
6	Integration and test	66	34	0	49,000
7	Evaluate NEWCP	0	0	100	125,000
8	Simulation tools preparation	0	90	10	65,000
9	Real-time issues	0	0	100	10,000
10	Final report	0	0	100	26,000
				TOTAL	643,000

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This report presents a functional design of the Electronic Warfare Control Processor (EWCP) processor and a proposed work plan and cost for Phase 2 of "The Integration of Electronic Warfare Assets on Maritime Platforms." The preliminary functional design elaborates on the i) main components of the EWCP, ii) functionality of components and component inter-relationships, iii) dataflow between components, and iv) distribution of functionality between the CCS and the EWCP. The design provides sufficient detail to support the definition and specification of the implementation work to be carried out in Phase 2.

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